

Are Detonator Qualification and Lot Acceptance Test Requirements Rational?

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Most of the discussion here pertains mainly to Exploding Foil Initiators (EFIs, slapper detonators)

➤ Discussion of various LAT and qualification tests

- Leak tests
- Electrical tests
- Radiographic inspections
- Functional tests
- Threshold tests

➤ Recommendations

... or are they detonator myths?

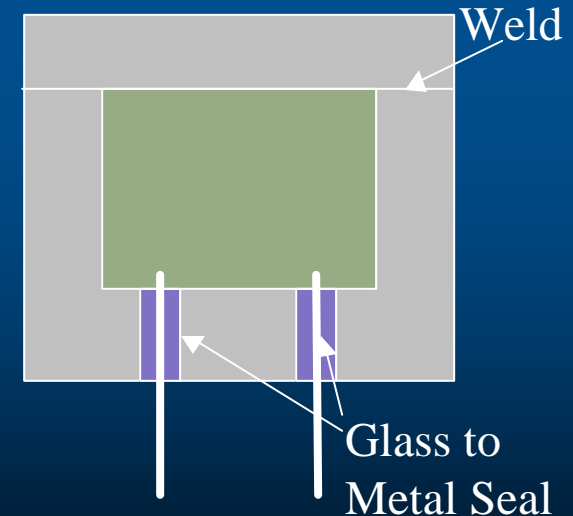
- **Many fuze and detonator requirements specify a maximum leak requirement**
 - **Hermetic**
 - Usually performed with helium leak detector
 - Many different definitions (10^{-5} , 10^{-9} cm³/s @ STP)
 - Many people assume that water (air) can not enter hermetic component
 - **No gross leak (bubble leak)**
 - Look for leaks in components submersed in liquid
 - **No leak requirement**

... and how well do they tell it?

- Assume component is empty cavity with one or more entry holes
- Bombard component with internal cavity of volume V in helium atmosphere for time T at pressure P , and measure indicated leak rate, l , within time t , to determine true leak rate, L
- Back up with gross leak test to ensure all helium does not leak out before making the helium measurement



$$l = L \left(1 - e^{-LT/V} \right) e^{-Lt/V} P / P_{atm}$$



... depends on several assumptions

- **Measured leak rate is not the true leak rate**
 - Complicated function of test conditions, some of which may not be known
 - Internal free volume
 - Diffusion rate of helium gas into energetic powder
- **Helium is not the only gas that will get into hermetic cavities**
 - Helium is used for experimental reasons: it is rare, easy to detect, and has a leak rate 3.7 time faster than air
 - Water vapor will easily penetrate components with a leak rate of $5 \cdot 10^{-6}$ (0.2 μm diameter, 1000 times water molecule)

- **Gross leak tests are generally not needed to back up fine (helium) leak tests of detonators**
 - Diffusion of helium into explosive powder significantly extends measurement time, often to more than one hour
- **“Hermetically sealed” components welded in inert atmosphere are not sealed & will contain normal air**
 - If cavity is sealed to 5×10^{-6} , and has an internal free volume of $.05 \text{ cm}^3$, it will undergo one complete air replenishment in 10^4 seconds (2.8 hours)
 - If a typical detonator is required to remain sealed for 10 years, then a leak rate of less than 10^{-10} is required (lower than background level on most systems)

- **Many electrical tests are used to characterize reliability and safety**
 - Hi current no-fire (AC & DC)
 - Electrical resistance
 - Pin-to-Case ESD (with a 500 or 5000 ohm series resistor)
 - Most specifications also require a 500 volt Hi-Pot with a leakage current less than 10 μ A, => a 50 MegaOhm internal resistance, a series resistor has no effect
- **Several electrical tests are of marginal use**
 - Pin-to-Pin ESD test through 500 or 5000 ohm resistor
 - Some Hi-Pot tests
 - Many Hi-Pot tests measure the humidity in the air, not the device
 - Many components will function properly at firing voltages above Hi-Pot failure voltages

... others are of marginal value

- **Standard ESD test: 500 pF capacitor charged to 25,000 Volts, discharged through a 500 and 5000 Ohm resistor pin-to-pin**
 - **The 156 mJ energy is sufficient to cause degradation and possibly initiation IF it is applied to sensitive element**
 - **There is no way to couple all of this energy into the bridge element of a modern detonator**
 - **Modern detonators have a bridge resistance < 50 mOhm**
 - **When discharged with 500 Ohm in series, only .01% or 15.6 uJ of energy is deposited in bridge**
 - **Maximum current (50 amps) and voltage across bridge (2.5 volts) for such a short time has NO effect on bridge**
 - **If there are no effects with a 500 Ohm resistor, then there can not be any with 5000 Ohm resistor!**

... has rarely uncovered problems not seen by other tests

- **Radiographic inspection is often required for both qualification and lot acceptance testing**
 - **X-ray finds defects in the metal pieces**
 - **N-ray finds defects in the explosive and plastic pieces**
- **The critical elements of modern detonators are small and hard to see with x-ray and n-ray**
 - **Cracks or defects in bridge are essentially impossible to see through the much thicker metal case (can readily find with resistance measurement)**
 - **Resolution insufficient to find cracks in explosive powder (Can not see explosive powder in the barrel of an EFI in sufficient quantities to dud)**

... but not the defects that cause failures in modern dets

- **Dent block measurements are often used to measure explosive output**
 - Dent depth
 - Dent shape
- **Often, explosive component residue can also indicate detonation**
- **A device that produces a larger dent may not have a greater probability of initiating next assembly**
- **Dent depths at colder temperature are lower because the dent material has changed, not the explosive output**

... about as well as looking at the component residue

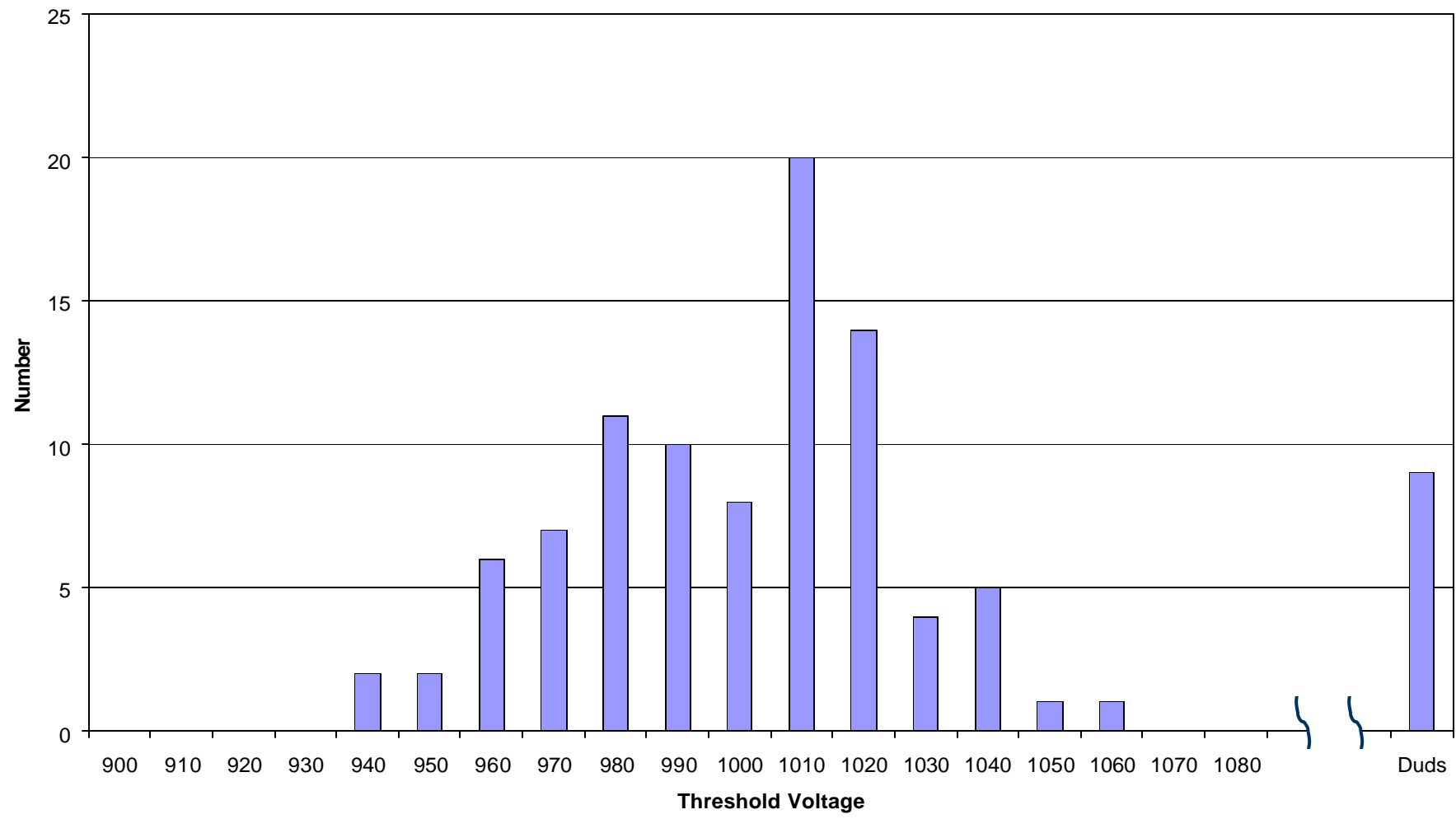
- **Many specifications require that a component have an All-Fire (0.999 reliability at 95% confidence) of less than xxxx volts**
 - **Threshold tests (Bruceton, Langlie, Neyer D-Optimal) can determine variation in the current, voltage, ... needed to initiate the device**
 - **Threshold tests can give an indication of the POSSIBILITY that a system COULD have an All-Fire less than the required level, but can not demonstrate system reliability**
 - **Threshold tests CAN NOT determine if even a large fraction of devices are duds!**

... but CAN NOT determine device reliability

Consider a sample from a reasonable lot ...

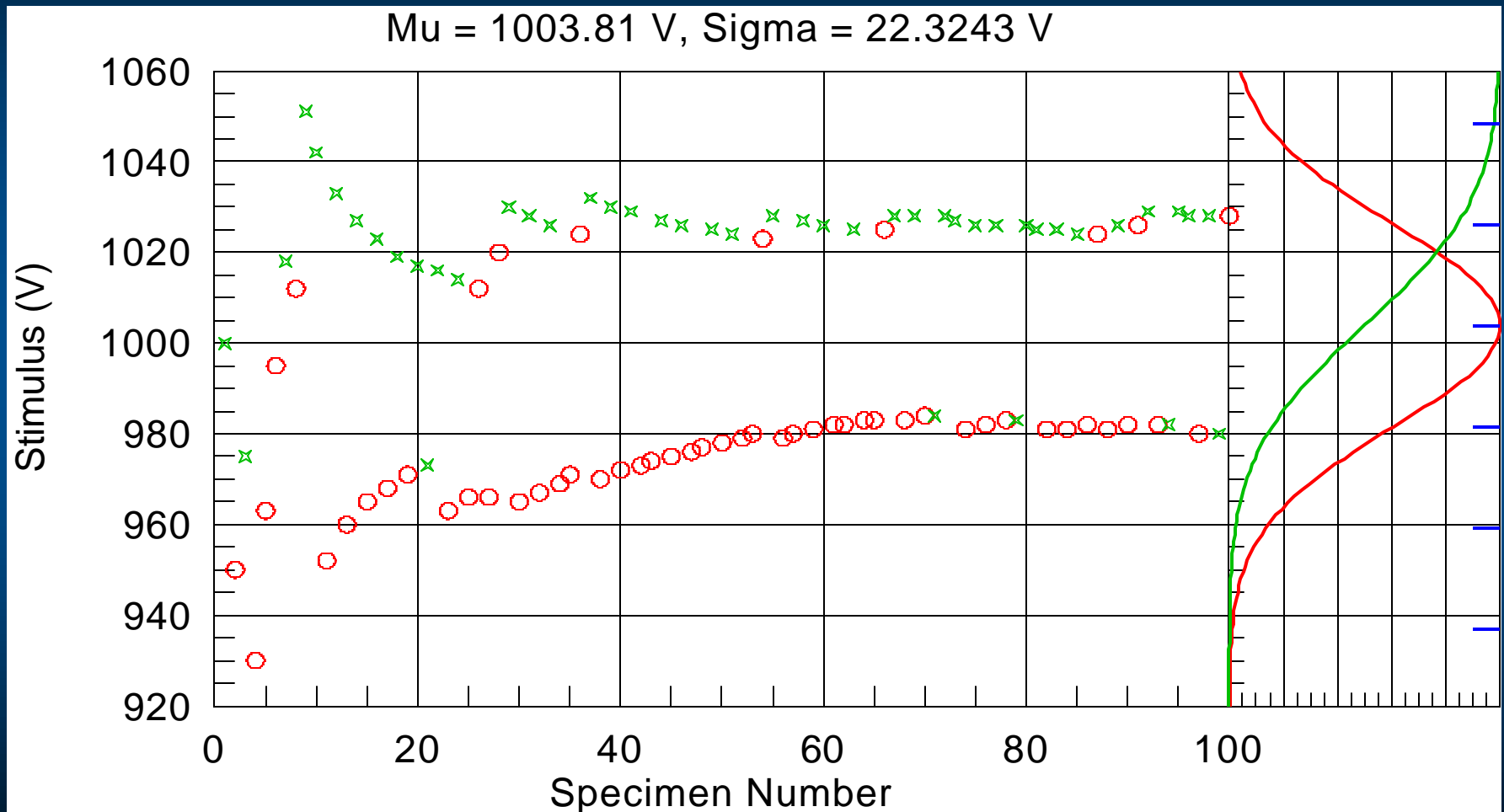


Distribution of Threshold Values, Mean 1000, Std Dev 25, 10% Duds



... but with a 10% dud rate

Threshold tests can not distinguish ...



... the “high” no-fires from a 10% dud rate

- **Must fire a large quantity of devices with no failures to establish reliability**
 - To establish 99.9% reliability at 95% confidence would require firing almost 3000 detonators!
- **There is no reason to EVER perform an older, inefficient threshold test**
 - Bruceton and Langlie tests were designed when computers were not available to analyze or assist in testing
 - These tests ALWAYS result in less knowledge about the population
 - There is no need to continue to use an old procedure to compare new test data with old test data
- **Small deviations from any procedure DO NOT have any major effect on efficiency or analysis**

... can allow determination of device variation

- **When revising specifications, or requiring tests for a component, there needs to be at least one person who understands each test and can provide a good engineering/scientific requirement for the test**
 - **Doing tests just because they have always been required is not sufficient justification**

- **Need to ensure that the sample size is large enough, that the variation in the hardware spans the allowed range, and that the environments are more severe than those required by lot acceptance tests**
 - **Qualifying devices that are built to a drawing package DOES NOT qualify the design**

... we must ensure that we get the maximum information

➤ **Leak tests**

- Eliminate requirement for gross test after fine leak test
- Examine real leak requirements

➤ **Electrical tests**

- Eliminate pin-to-pin ESD test with resistor
- Examine real Hi-Pot requirements

➤ **Radiographic inspections**

- Eliminate blanket requirement, use when appropriate

➤ **Functional tests**

- Eliminate dent requirement, use when appropriate

➤ **Threshold tests**

- Use modern test, and adapt when necessary
- Do not rely on threshold tests to prove reliability

... can lead to more reliable components at reduced cost